Environmental optimization of in situ thermal remediation using life cycle assessment (LCA)

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Abstract

In situ thermal remediation technologies such as In Situ Thermal Desorption (ISTD), Electro Thermal – Dynamic Stripping Process (ET-DSP) and Steam Enhanced Extraction (SEE) have proven to be efficient and rapid methods for cleanup of chlorinated solvent source zones. While avoiding the adverse impacts of excavation and off-site treatment, in situ thermal remediation methods require a lot of energy as well as material use for on-site installations and equipment. The aim of this study is to conduct a detailed life cycle assessment (LCA) of remediation using ISTD, ET-DSP and SEE respectively to assess the environmental impacts and the drivers of these impacts for each technology. Based on this, options for reducing the environmental impacts of each technology by e.g. substitution of materials and change in heating strategies will be evaluated using LCA and recommendations for reducing the environmental impacts will be provided.

Life cycle assessment is an established and systematic methodology for assessing the environmental impacts associated with the entire life-cycle (from “cradle-to-grave”) of a certain product or service. The environmental exchanges during the life-cycle of the remediation service (use of finite resources, emissions to air, soil and water) are translated into a number of environmental impacts including global warming, ozone formation, acidification, eutrophication, respiratory impacts, human- and ecotoxicity and resource use. The wide range of impacts included in the assessment gives a more complete and holistic assessment than methods focusing only on single indicators such as “carbon footprint”. The LCA of a remediation project includes all activities related to the remediation project including processing and manufacturing of energy and materials taking place upstream in the system and waste management taking place downstream in the system. This is illustrated in Figure 1.

As a basis for conducting the LCA, a thorough data collection phase was carried out in order to establish a baseline dataset for each technology in terms of energy use, material use, the use of equipment during construction and transportation activities for each remediation technology. The assessment covers all parts of the remediation projects, i.e. the well field materials and establishment, the capping materials, the air and water treatment systems, the electricity use and the transportation of materials and personnel. The data collection and the LCA was conducted for two sites contaminated with chlorinated solvents – a small (180 m^2) and a larger site (1300 m^2) respectively. The data inputs for these sites were based on two actual Danish sites where remediation using ISTD has been conducted.

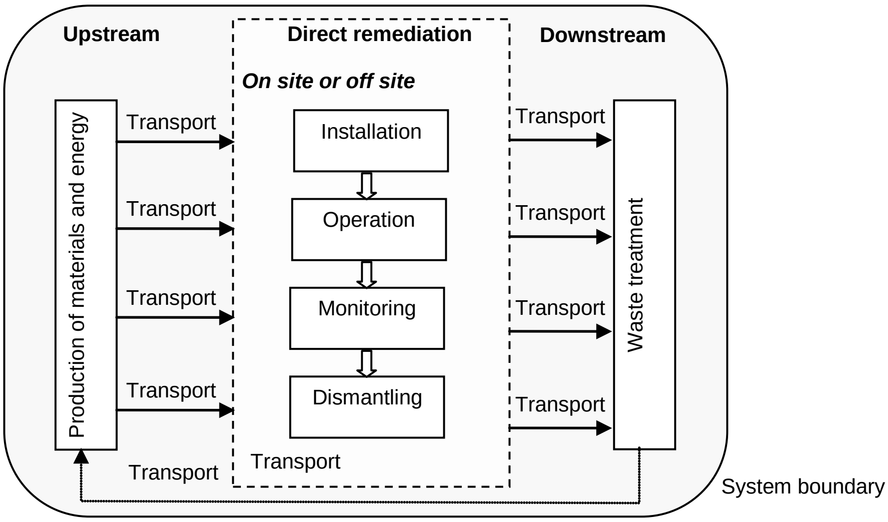

Figure 1. Direct and indirect activities associated with contaminated site remediation

The results show that the on-site energy use is the main cause of environmental impacts together with the use of a concrete vapor cap, granular activated carbon and steel/stainless steel for the well field. A number of different options for reducing the environmental impacts of the three thermal remediation technologies were evaluated using LCA. The identified improvement options depend on the thermal technology considered. If electricity from the Danish grid is applied it can be beneficial to focus the heating outside the peak demand periods in order to avoid increased production by marginal electricity production which in Denmark mainly is coal-based. Two general findings applying to all the assessed thermal technologies were identified; these are the use of vapor cap types containing less concrete and the use of coconut shell-based activated carbon in place of anthracite-based activated carbon for the treatment of the extracted vapors. In addition to these finding specific options for substitution of material types for the construction of wells and heaters were identified in order to reduce the depletion of scarce resources. If all identified improvement options are implemented, the combined reduction in environmental impacts is in the order of 10-20% and the combined reduction in resource depletion is 8-20%.